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ENVIRONMENTAL GEOLOGY NOTES

NOVEMBER 1976 • NUMBER 80

SUPPLEMENT TO THE FINAL REPORT ON THE HYDROGEOLOGY OF SOLID WASTE DISPOSAL SITES IN NORTHEASTERN ILLINOIS

George M. Hughes, John A. Schleicher, and Keros Cartwright

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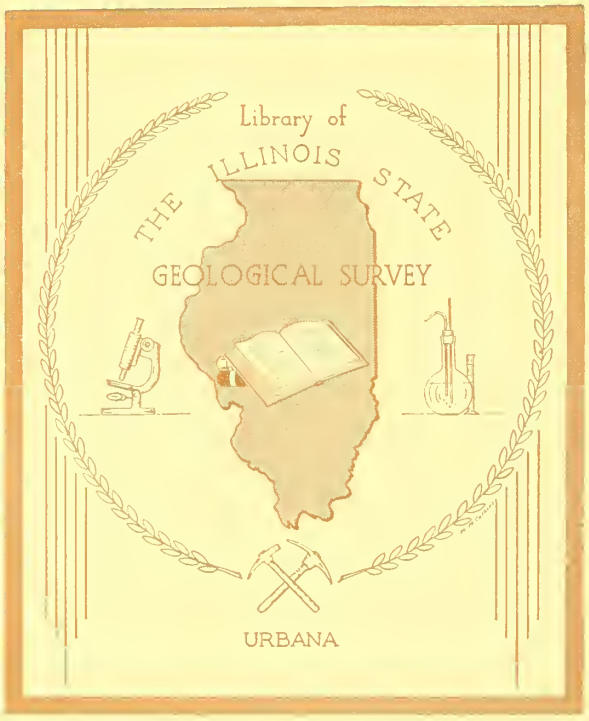
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Supplement to the Final Report on the

HYDROGEOLOGY OF SOLID WASTE DISPOSAL SITES IN NORTHEASTERN ILLINOIS

George M. Hughes, John A. Schleicher, and Keros Cartwright*

INTRODUCTION

In 1966 the Illinois State Geological Survey received a demonstration grant from the Solid Waste Management Office of the United States Environmental Protection Agency (EPA) to study the hydrogeology of solid waste disposal sites in northeastern Illinois (Fig. 1). This work was completed in 1970 and a final report was submitted to the Solid Waste Management Office (Hughes et al., 1971a). The Illinois State Geological Survey continued to gather data from the disposal sites until the spring of 1973; this report represents a compilation of those data.

There have been no major changes in the conclusions and interpretations presented in the Geological Survey's final report to the EPA. However, additional work was necessary to verify the data on infiltration and water quality since that phase of the final report was based on only one year of records. Basic data, such as the location of the borings, have not been included in this supplemental report. The reader should refer to Hughes et al. (1971a and b) for this information.

This report is divided into two parts. The first deals with the hydrogeology of the solid waste disposal sites; the second deals with the quality of the water in the vicinity of these sites. The appendix lists the analytical procedures that were used.

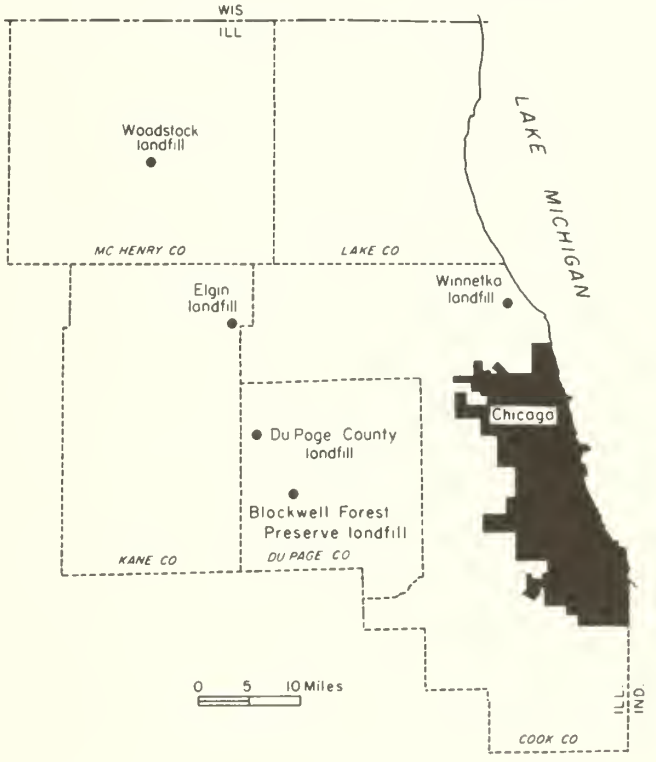

Fig. 1 - Locations of landfill sites investigated.

*Ontario Ministry of the Environment, Toronto, Ontario CANADA M4V 1P5.

HYDROGEOLOGIC DATA

Infiltration

Table 1 (an updating of Table 19 in Hughes et al., 1971a) presents data on infiltration and specific yield at four landfill sites for the period 1968 to 1972. This table shows that: 1) Calculations of recharge (cumulative annual rise in the hydrograph x specific yield), based on continuous hydrographs, and calculations of recharge, based on hydrographs constructed from weekly measurements, yield similar values. 2) The values for the specific yield (effective porosity) of the refuse are on the order of 25 percent and do not show decreasing values with increasing age of refuse, as was indicated by Hughes et al. (1971a, Fig. 23). 3) In most cases variations in the annual precipitation resulted in similar variation in annual recharge. 4) Annual recharge was, for the most part, less than one-half of the annual precipitation.

Depending upon climatic conditions and upon recharge by precipitation, production of leachate in the landfill can occur in all months of the year. Figure 2 is a graph of the cumulative monthly hydrograph rise at DupLW7

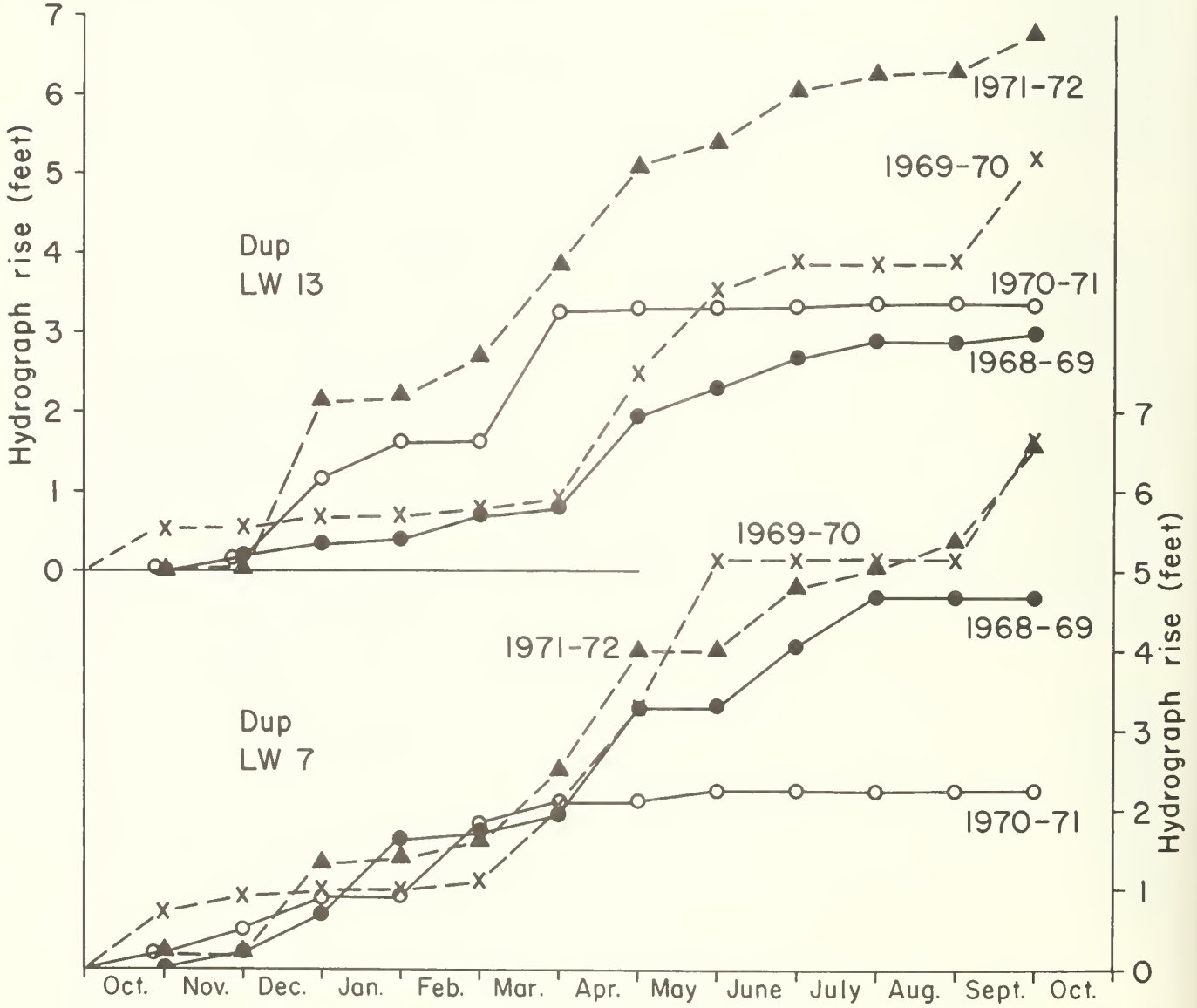

Fig. 2 - Graph showing cumulative monthly hydrograph rise from October 1, 1968 to October 1, 1972.

TABLE 1 - DATA ON INFILTRATION AND SPECIFIC YIELD

	Water year (10/1 to 9/30)	Type of record	Du Page LW7	Du Page LW13	Du Page MM29	Du Page MM32	Winnetka LW5B	Winnetka LW13	Winnetka LW17	Winnetka MM11	Woodstock LW6B	Woodstock LW7	Woodstock LW8	Elgin[2] LW4D	Elgin[2] LW7B	Elgin[2] LW10
Cumulative hydrograph rise (feet)	1968-69	Weekly records	4.73	3.00	4.30	4.40	8.45	3.75	3.81	3.80	2.65	3.90	1.50	5.60+	2.52	4.90
		Continuous records	5.58	3.03	-	-	-	4.16	1.67+	-	-	3.91	1.53 est	-	2.00	-
	1969-70	Weekly records	6.65	5.20	5.61	6.56	12.01	3.72	4.20	4.84	4.35	5.60	1.75	8.25	3.65	-
		Continuous records	6.69	4.80	-	-	-	3.27	4.76	-	-	5.43	1.36	-	-	-
	1970-71	Weekly records	2.26	3.37	2.74	3.33	6.24	3.18	8.37	1.79	2.35	1.65	2.75	8.45	1.30	-
		Continous records	2.21	-	-	-	-	2.05	-	-	-	-	-	-	-	-
	1971-72	Weekly records	6.62	6.78	6.43	6.14	8.84	4.26	9.59	-	3.95+	4.75	4.80	17.45	5.80	-
		Continuous records	7.16	6.79	-	-	-	4.67	10.31	-	-	-	5.34	-	-	-
Estimated specific yield (percent)			20-25	25-30	20-30	20-30	20-25	25-30	25-30		25-30	25-30	25-30		20-25	
Total recharge (feet)	1968-69		1.26	.83	1.08	1.10	1.90	1.44	1.05		.72	1.08	.42		.57	
	1969-70		1.51	1.32	1.40	1.64	2.70	.90	1.31		1.20	1.49	.37		.82	
	1970-71		.50	.93	.69	.83	1.40	.56	2.30		.64	.45	.76		.29	
	1971-72		1.61	1.87	1.61	1.54	1.99	1.28	2.83		1.09+	1.31	1.47		1.31	
Year refuse buried			1954	1963	1960	1955	1948	1953	1967	1964	1963?	1963?	1967	1958	1954-1958?	1958?
Precipitation[1] (inches)	Barometric efficiency (percent)		10-30	10-25				10-25	15-25			0-20	0-20		0-20	
	1968-69			28.77				34.79				27.12			30.41	
	1969-70			38.57				38.55				39.16			46.99	
	1970-71			20.15				26.48				22.54			24.83	
	1971-72			40.43				40.78				53.80			49.89	

[1]Rain gauge at Du Page County was sheltered. True precipitation was probably four inches greater than shown. Elgin precipitation data were from U.S. Department of Commerce records; other data were from Illinois State Geological Survey instruments.

[2]Measurements at Elgin were poor because of erratic hydrographs and flooding.

and DupLW13 (located at the Old Du Page County landfill) for successive years beginning October 1, 1968. The following conclusions can be drawn from these data: 1) There is little recharge in January or February because the ground is frozen. 2) In March, April, and early May, recharge is greatest because of the spring thaw, the high precipitation, and the low evapo-transpiration during these months. 3) By late May the temperature has increased and vegetation is established so that recharge decreases as the evapo-transpiration increases; during the period from late May through August, recharge occurs only after a series of relatively large rainfalls. 4) In September, October, November, and December temperatures are again lower, vegetation is dying, and evapo-transpiration has decreased; during these months there is usually a significant amount of recharge, though not as large as that occurring in the spring.

Figure 3 is a graph of the percentage of the monthly precipitation that infiltrates through the landfill to the water table. These data illustrate the fact that the production of recharge and leachate is related not only to monthly precipitation, but also to soil moisture conditions, freezing or thawing conditions, and the intensity and duration of individual precipitation events. Recharge that is in excess of that normally caused by precipitation may be caused by snow and brief winter thaws, as is illustrated in Figure 3 by the high recharge values for January 1969, February 1971, and February 1972. The high values in April 1969, March 1970, and April 1972 were caused by the frost coming out of the ground during the spring thaw, coupled

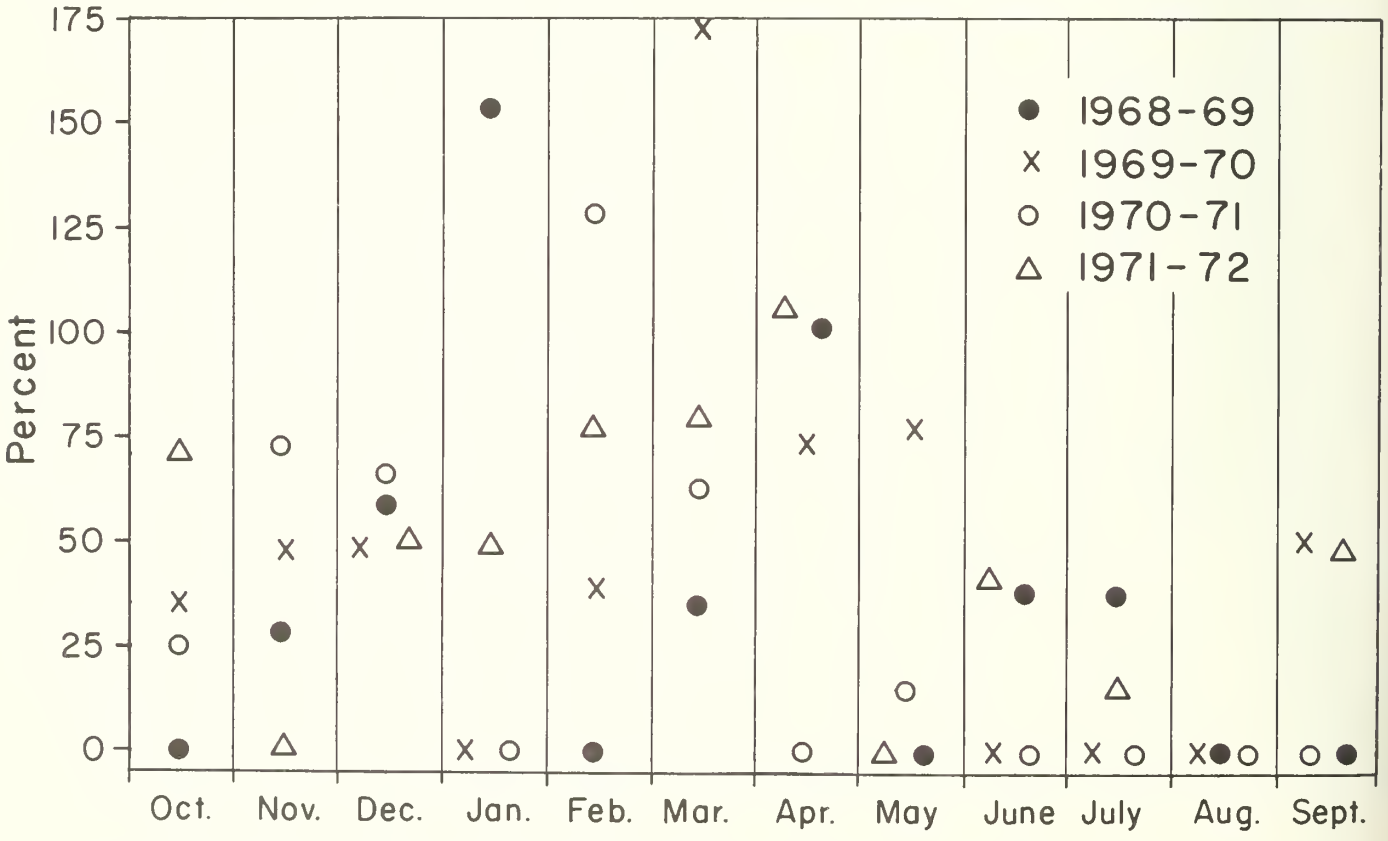

Fig. 3 - Graph showing the percent of monthly precipitation infiltrating through landfill to water table at DupLW7 from October 1, 1968 to October 1, 1972.

with spring rains; the high values in July 1969 and September 1970 were caused by relatively heavy, continuous precipitation. The yearly pattern of recharge and accompanying leachate production will influence the sizing of collection and treatment facilities.

Specific Yield

The value of specific yield (sometimes referred to as the effective porosity) for refuse is obtained by dividing the amount of water entering the refuse (precipitation) by the resultant rise in the hydrograph when the refuse is at field capacity. The values given in Table 1 are estimates based on subjective interpretation of data. Low values for specific yield are generally calculated from hydrographs made in late winter and early spring; high values, from hydrographs made during the rest of the year.

The low values of specific yield are calculated when precipitation is supplemented by additional water from melting snow or ice, or from the frost in the ground melting and moving to the water table. Under these circumstances, the hydrograph may exhibit a gradual rise that does not reflect individual precipitation events and a rise that continues for one to three weeks. A low value is also obtained when the water level is in the cover material on top of the refuse. This is a true specific yield that applies to the landfill cover only, rather than to the refuse.

High values of specific yield are obtained when part of the precipitation that falls does not infiltrate the refuse. This may occur when the precipitation falls as snow, when there is runoff from intense rain, or when ice is formed in frozen ground. High values also result when evapo-transpiration lowers the moisture content of the cover material and the unsaturated refuse to below field capacity; then a portion of the infiltrating water is required to satisfy this moisture deficiency.

Calculations of both specific yield and infiltration are affected by barometric changes and by rapid rises in water levels. Barometric effects are not consistent throughout the year; they seem to be magnified by a high moisture content in the landfill cover or by frozen ground. Rapid rises in water levels may be related to the downward movement of a wetting front from a rain or thaw, and, possibly, rises may be related to the loading of the landfill and to the compression of the refuse by the weight of snow or water on the cover of the landfill.

Field Capacity

The amount of water necessary to bring the refuse that lies above the zone of saturation to field capacity would influence the rate of development of a ground-water mound, and, ultimately, the amount of leachate produced as springs or that flows to a treatment facility. Field capacity is the amount of water held by the soil (or refuse) against the pull of gravitational draining. Our judgment of when field capacity has been reached is quite subjective; it is based on the general configuration of hydrographs of wells that are completed in the refuse. The hydrographs from wells in older refuse, which we assume has reached field capacity, show a more rapid response to infiltration events and to smaller amounts of infiltration, than do the hydrographs from wells that are completed in younger refuse.

Data that could determine how much water was actually needed to bring the refuse to field capacity and how great an effect this need would have on leachate discharge from a landfill were not available from the hydrographs. There is some question that a hydrograph that shows little response to precipitation does, in fact, indicate that the refuse has not reached field capacity. However, the water that is required to bring refuse to field capacity and to develop a ground-water mound would act to reduce the amount of leachate that is produced from a landfill until these requirements are satisfied. It appears that in these particular landfills field capacity was reached in 4 to 7 years.

Development of Ground-Water Mound

Table 2 shows changes in the annual low water level in the landfills between 1968 and 1973 as measured by piezometers placed in refuse. During the winter of each of these years, there was a one- to two-week period of relatively stable water levels when the ground was frozen. This commonly corresponded with the annual low water level; these are the values on which Table 2 is based. The water levels in a well point placed in younger refuse, such as at Du Page LW13 and Winnetka LW17, show a consistent rise each year, whereas the water levels in a well point in older refuse, such as Du Page LW7 and Winnetka LW13, tend to maintain a relatively constant elevation.

We believe that these water-level data indicate that the ground-water mound in the older refuse is in equilibrium with infiltration. The mound will rise in response to the infiltration of the precipitation and then fall to its original level as the ground water drains away through the sides and base of the landfill. In younger refuse the ground-water mound continues to grow each year, and the mound does not decline to its original level during dry periods. Also the water-level rises are greater during periods of high precipitation than are shown in the well points in the older refuse.

The growth of a ground-water mound will promote the development of springs along the margin of the landfill, but until this mound is fully developed the amount of spring flow will not reach its maximum. The absence of a consistent relationship on Table 2 suggests that the rate of growth is influenced by factors other than the age of the refuse. An example of the inconsistency is shown by Du Page LW13, which is in refuse buried in 1963, but shows a larger increase

TABLE 2 - CHANGES IN LOW WATER LEVELS DURING WINTER FROM 1968 TO 1973*

Well no.	Year of burial	1968-69† (ft)	1969-70 (ft)	1970-71 (ft)	1971-72 (ft)	1972-73 (ft)
Du Page						
LW7	1954	0	-0.25	+0.35	-0.65	+0.85
MW32	1955	0	-0.25	+0.75	-1.80	+0.10
MW29	1960	0	+0.80	+1.75	-0.40	+1.50
LW13	1963	0	+1.55	+3.80	+3.10	+5.00
Winnetka						
LW5B	1948	0	-0.25	-1.25	+0.15	-1.35
LW13	1953	0	+0.25	-0.60	-0.70	0
LW11	1964	0	+0.50	+0.25	+0.15	0
LW17	1967	0	+0.90	+2.40	+2.50	+3.90?
Woodstock						
LW6B	1963?	0	0	+0.15	-0.10	+0.70
LW7	1963?	0	-0.20	+0.30	-1.20	+0.85
LW8	1967	0	-0.30	+0.40	-0.35	+1.45

* Low value during a period when the hydrograph is relatively flat because the mean daily temperature is nearly freezing

† First year of measurements.

in water level than is apparent in Woodstock LW8, which is in refuse buried in 1967. Other factors that could influence changes in water level include the thickness of the refuse, its initial moisture content, its specific yield, the permeability of the materials beneath the refuse, the available ground-water gradient, and the amount of precipitation and infiltration through the cover. The relative significance of these various factors was not apparent from the available data. As a matter of interest, in the landfills that we studied that initially contained 10 to 20 feet of unsaturated refuse, 10 to 15 years were required for the ground-water mound to reach equilibrium.

WATER QUALITY DATA

Detailed water quality analyses were obtained in 1969 and presented on Table 9 of the Final Report (Hughes et al., 1971a). Detailed analyses were again obtained for samples taken in 1970, 1971, and 1973. These data are presented in Table 3 of this report. These samples were analyzed by the four different laboratories listed in the footnotes of Table 3. The variations in analytical results are probably similar in magnitude to those that would be obtained during a carefully run monitoring program. The analytical methods that were used to obtain the values given in Table 3 are in the Appendix.

Sampling Procedures

No attempt was made to determine whether different sampling procedures affected the analytical results. In each case, the method used to sample an individual monitoring point was based on the characteristics of that monitoring point (that is, diameter, water level) and the equipment that was available.

The following general procedures were followed for all samples:

1) The old water was removed from each sampling point and new ground water was allowed to enter before a sample was taken. This was accomplished by pumping until at least three times the volume of the water initially present in the monitoring point had been discarded, or by pumping the monitoring point completely dry and allowing "fresh" formation water to accumulate. If foreign material was still present, the monitoring point was rinsed with clean water, pumped dry, and allowed to refill before the sample was taken.

2) The sampling equipment was cleaned with tap water after each sample was taken and rinsed with water being discarded from the monitoring point.

3) As many field measurements as possible, including pH and conductivity, were obtained.

4) Sample bottles were filled to the top and taken to the laboratory within 24 hours, generally in a cooler.

5) If there was a significant amount of sediment suspended in a

sample, the sediment was allowed to settle for up to 10 minutes before bottling.

6) One bottle of sample was acidified and the other was generally left as taken. Attempts were made to filter samples in the field before transporting them to the laboratory; however, this procedure proved too time-consuming and most samples were therefore filtered in the laboratory.

7) Whenever possible, all of the samples from a given landfill were obtained during a single day. If this was not possible, sampling was avoided during periods of rain or thaw.

The various sampling points are ordered, for the most part, to show migration distance from the landfill (Table 3). If earlier sampling points were destroyed, new sampling points were selected to duplicate conditions as closely as possible. The wells that were sampled are listed in Table 4. The reader is also referred to the Hughes et al. (1971a) report for maps of the landfills.

Table 3 is divided into four parts to simplify presentation. Table 3A presents the results of analyses of organic and miscellaneous components and 3B, 3C, and 3D, the anions and the cations. In different years, analyses of leachate from the same boring give different results, even when climatic conditions immediately preceding the sampling are relatively similar. Some variations are probably not real and were caused by difficulties encountered in obtaining consistent samples and by delays in running the analyses. Other variations may have been caused by interferences that are present in analyses of complex, concentrated solutions such as refuse leachate.

Some variations in the quality of the leachate are real and probably are related to the climatic and hydrogeologic factors discussed in the final report (Hughes et al., 1971a). With the exception of the effect of the travel distance and the earth materials through which the leachate traveled, the factors responsible for these variations in quality are not apparent in Table 3. The relationship between earth materials, travel distance, and attenuation is most apparent in the analyses for alkalinity, conductivity, total dissolved solids, ammonia, boron, calcium, magnesium, potassium, bicarbonate, bromine, chlorine, copper, and sodium.

(See Discussion and References, page 22)

TABLE 3A - RESULTS OF CHEMICAL ANALYSES OF ORGANIC AND MISCELLANEOUS COMPONENTS FROM SELECTED SAMPLING POINTS
(See Table 4 and Hughes et al. (1971a) for location.)

		1	2	3	4	5	6	7	8	9	10	11	12	13
Sample no.	Year tested	Alkalinity[1] (ppm)	Alkalinity[2] (ppm)	Biological oxygen demand (ppm)	Chemical oxygen demand (ppm)	Conductivity[1] (MMHOS/CM[2])	Conductivity[2] (MMHOS/CM[2])	Total hardness (ppm)	Hexane solubles (ppm)	M.B.A.S.[3] (ppm)	Pesticides (ppm)	pH	Total dissolved solids (ppm)	Ammonia (ppm)
DupLW6A	1969	530†	252	10†	7†			300†	11†	0.02†		7.3	352†	
	1970			20*	39*	715				0.2*		6.9	358	
	1971	330#			120*	650	650*					6.8	330	
	1973	320#			12*	400	600*	340#				6.8	350	0.55*
DupLW14	1969	630†	247	230†	284†			260†	0†	0.06†		6.9-7.0	372†	
	1970			29*	30*	750				0.3*		7.1	368	
	1971	330#			160*	700	720*					6.7-6.8	380	
	1973	300#			105*	340	600*	260#				7.0	380	0.55*
DupLW15	1969	750†	337	59†	52†			440†	7†	0.02†		6.9-7.0	606†	
	1970			8*	23*	1150				0.2*		6.9	722	
	1971	430#			200*	1000	1120*					7.0	760	
	1973	616#			24*	925	1600*	580#				6.8	920	1.8*
DupLW16	1969	1100†	1369	60†	96†			880†	7†	0.04†		6.9-7.0	1334†	
	1970			25*	73*	2200				0.4*		7.4	1342	
	1971	860#			520*	2000	2460*					7.0	1120	
	1973	772#			63*	1250	2600*	840#				6.8	1430	3.8*
DupLW6B	1969	2250†	1011	225†	40†			540†	7†	0.30†		7.0	1198†	
	1970			46*	160*	2400				0.9*		6.8	1028	
	1971	1240#			380*	2700	2940*					7.0	910	
	1973	1180#			190*	1600	2600*	460#				6.8	800	166.0*
DupLW12A	1969	640†	258	53†	207†			350†	0†	0.02†		6.2	564†	
	1970			27*	30*	1120				0.2*		7.1	626	
	1971				3250*	1900	PS*					7.0	7230	
	1973	520#			155*	1200	1400*	420#				6.0	820	0.52*
DupLW11A	1969	550†		290†	36†			280†	8†	0.04†		7.4	446†	
	1970			3*	10*	1100				0.2*		7.35	512	
	1971					1500						7.0	9900	
	1973	472#			20*	530	840*	370#				7.2	630	0.40*
DupLW5B	1969	5810†	4159	14080†	8000†			2200†	18†	0.72†		6.3	6794†	
	1970			>200*	830*	>8000				2.6*		6.7	4924	
	1971	4800#			2600*	>8000	13160*					7.5	4580	
	1973	2900#			435*	6000	7800*	1000#				8.0	2880	364.0*

<5 micrograms, all BDL

[1,2] Sample split for analysis at two laboratories.
[3] Methylene blue active substances (includes detergents).
ND - Not determined. TR - Trace.
PS - Poor sample or not suitable for testing.

— - Analysis by Illinois State Geological Survey.
* - Analysis by Illinois State Department of Public Health.
† - Analysis by Tenco Hydro/Aerosciences, Inc.
# - Analysis by Illinois Environmental Protection Agency.

TABLE 3A - RESULTS OF CHEMICAL ANALYSES OF ORGANIC AND MISCELLANEOUS COMPONENTS FROM SELECTED SAMPLING POINTS
(See Table 4 and Hughes et al. (1971a) for location.) - Continued

		1	2	3	4	5	6	7	8	9	10	11	12	13
Sample no.	Year tested	Alkalinity[1] (ppm)	Alkalinity[2] (ppm)	Biological oxygen demand (ppm)	Chemical oxygen demand (ppm)	Conductivity[1] (MMHOS/CM[2])	Conductivity[2] (MMHOS/CM[2])	Total hardness (ppm)	Hexane solubles (ppm)	M.B.A.S.[3] (ppm)	Pesticides (ppm)	pH	Total dissolved solids (ppm)	Ammonia (ppm)
DupMM79	1970			12*	18*	890				0.2*		6.4	552	
	1971	360#			110*	900	860*					6.8	440	
	1973	408#			130*	450	990*	460#				7.0	560	0.10*
DupMM48	1969	540†		36†	68†			410†	3†	0.01†			622†	
DupMM59	1969	2130†	428	180†	348†			900†	5†	0.06†		7.0	1620†	
	1970					2800						7.05	1326	
DupMM23	1971												1020	
	1973					800						6.8	1100	
DupMM42	1973	2800#			225*	1500	3900*	560#				6.8	1430	178.0*
DupMM44	1969	5000†	1968	6960†	8200†			3180†	3†	0.152†	<5 micrograms, all BDL	6.6	1270†	
	1970			230*	2720*	4000				1.4*			3444	
	1971	1850#			9000*	3500	7350*					6.5	5850	
DupMM61	1969	1630†		125†	360†			690†	5†	0.210†			1104†	
DupMM63	1969	4720†	2646	4560†	2940†			2250†	6†	0.260†			5910†	
	1970			>200*	650*	>8000				3.2*		6.5	5354	
	1971	5000#			3000*	>8000	15780*					7.0	6030	
	1973	4220#			660*	5000	14100*	1100#				7.0	4900	672.0*
WinnLW10A	1970			24*	94*	950				0.6*		7.9	632	
	1971				4000*	1000	PS*					6.8	860	
	1973	480#			385*	720	1750*	560#				6.8	1110	5.2*
WinnLW12	1969	940†	422	24†	48†			560†	3†	0.012†		7.0	678†	
	1971	550#			140*	1100	1360*					6.5	880	
	1973	516#			24*	740	1480*	420#				7.0	840	0.30*
WinnLW13	1969	1450†	1424	105†	153†			710†	8†	0.15†			584†	
	1970			47*	140*	2200				0.6*		6.4	814	
	1971	1100#			370*	3500	2900*					6.8	1080	
	1973	552#			55*	650	1260*	490#				6.8	650	21.2*

[1,2] Sample split for analysis at two laboratories.
[3] Methylene blue active substances (includes detergents).
ND - Not determined. TR - Trace.
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		1	2	3	4	5	6	7	8	9	10	11	12	13
Sample no.	Year tested	Alkalinity[1] (ppm)	Alkalinity[2] (ppm)	Biological oxygen demand (ppm)	Chemical oxygen demand (ppm)	Conductivity[1] (MMHOS/CM[2])	Conductivity[2] (MMHOS/CM[2])	Total hardness (ppm)	Hexane solubles (ppm)	M.B.A.S.[3] (ppm)	Pesticides (ppm)	pH	Total dissolved solids (ppm)	Ammonia (ppm)
WinnLW5B	1969	3080†	1426	250†	415†			970†	4†	0.50†			994†	
	1970			60*	320*	3900				1.8*		6.8	1904	
	1971	1740#			600*	3800	6050*					7.0	2170	
	1973	1700#			375*	1000	6000*	740#				7.0	2050	244.0*
WinnLW17	1969	3370†	431	6400†	4260†			1180†	5†	0.35†			2306†	
	1970			60*	335*	3600				1.0*		6.3	1972	
	1971	1400#			200*	2200	2550*					7.0	980	
	1973	612#			63*	800	2100*	740#				7.0	1200	3.4*
ElgLW6B	1969	790†	302	14†	30†			1080†	7†	0.03†			1410†	
	1970			12*	37*	1650				0.3*		6.0	1008	
	1971	590#			2700*	1600	2120*					6.5	1710	
	1973					1000						6.8	2150	
WoodLW1C	1969	690†		40†	308†			470†	6†	0.08†			530†	
	1970			19*	31*	1250				0.2*		6.0	690	
WoodLW6B	1973												2220	
BlkLW1	1969	11570†	3255	54610†	39680†			7830†	350†				19144†	
	1970			>200*	19800*					6.0*			19810	
BlkLW2	1973	6000#			70740*		57000*	PS#					37510	PS*

<5 micrograms, all BDL

[1,2] Sample split for analysis at two laboratories.
[3] Methylene blue active substances (includes detergents).
ND - Not determined. TR - Trace.
PS - Poor sample or not suitable for testing.

— - Analysis by Illinois State Geological Survey.
* - Analysis by Illinois State Department of Public Health.
† - Analysis by Tenco Hydro/Aerosciences, Inc.
# - Analysis by Illinois Environmental Protection Agency.

TABLE 3B - RESULTS OF CHEMICAL ANALYSES OF ANIONS AND CATIONS FROM SELECTED SAMPLING POINTS
(See Table 4 and Hughes et al. (1971a) for location)

Sample no.	Year tested	14 Bicarbonate[1] (ppm)	15 Bicarbonate[2] (ppm)	16 Bromine (ppm)	17 Carbonate (ppm)	18 Chloride[1] (ppm)	19 Chloride[2] (ppm)	20 Cyanide (ppm)	21 Fluoride[1] (ppm)	22 Fluoride[2] (ppm)	23 Nitrate (ppm)	24 Phosphate[1] (ppm)	25 Phosphate[2] (ppm)	26 Sulphate[1] (ppm)	27 Sulphate[2] (ppm)	28 Aluminum (ppm)	29 Arsenic[1] (ppm)
DupLW6A	1969			<0.1		7†		<0.005†	0.35†		0.28†	<0.02†		16.0†		0.30†	6.6†
	1970	356				<10					<0.1*	ND	0.1*	<.05			
	1971	410		<0.06		<10	30*		0.5					15.0	28*		0.006
	1973	380				<10	6*		0.52		<0.05#	0.07*		<.05	21†		.0009
DupLW14	1969					17†		<0.005†	0.65†		0.66†	2.85†		16.4†		1.10†	5.9†
	1970	383				11					<0.1*	ND	0.1*	TR			
	1971	390		<0.2		<10	40*		0.85			<10		21	21*		<0.001
	1973	380				<10	22*		0.94		<0.05#	0.40*		5	10*		.0008
DupLW15	1969			0.4		94†		<0.005†	0.19†		0.32†	0.67†		26.0†		0.40†	3.8†
	1970	634				16					<0.1*	ND	0.2*	TR			
	1971	590		<0.1		75	87*		0.4			<10		80	79*		<0.001
	1973	770		0.98		170	180*		0.22		0.6#	0.13*		9	13*		.003
DupLW16	1969			1.3		309†		<0.005†	0.05†		1.00†	0.50†		14†		0.10†	<0.1†
	1970	860				325					<0.1*	ND	<0.1*	20			
	1971	1000		0.42		144	275*		0.3			<10		16	20*		0.002
	1973	1040		1.7		321	340*		0.18		<0.05#	0.12*		16	24*		.0003
DupLW6B	1969			2.8		135†		<0.02†	0.31†		1.60†	0.31†		2.0†		0.90†	4.6†
	1970	1130			163	120					<0.1*	ND	0.2*	ND			
	1971	1500		1.8		80	155*		0.1			<10		6	<10*		0.01
	1973	1440		1.3		58	185*		0.15		0.1#	0.50*		0.3	42*		.006
DupLW12A	1969			<0.1		12†		<0.005†	0.31†		0.40†	1.35†		97.5†		0.70†	6.0†
	1970	510				25					<0.1*	ND	0.1*	111			
	1971	780		<0.9		50	525*		0.4			<10		270			0.06
	1973	660		.94		100	140*		0.33		<0.05#	0.60*		11			.001
DupLW11A	1969			<0.1		7†		<0.005†	0.27†		0.28†	0.47†		100†		0.30†	<0.1†
	1970	420				<10					<0.1*	ND	0.2*	95			
	1971	600		<0.6					0.4					ND			0.14
	1973	580		.73		58	87*		0.25		<0.05#	0.03*		5	8*		.001
DupLW5B	1969			10		1330†		<0.005†	2.0		0.70†	1.20†		2.0†		0.10†	<0.1†
	1970	2603			5	247					1.00*	ND	PS*	ND			
	1971	5600		8.6		104	100*		0.14			54		3	6*		0.008
	1973	3460		1.5		480	600*		0.14		<0.05#	1.0*		4	160*		.005

[1,2] Sample split for analysis at two laboratories.
[3] Methylene blue active substances (includes detergents).
ND - Not determined. TR - Trace.
PS - Poor sample or not suitable for testing.

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# - Analysis by Illinois Environmental Protection Agency.

TABLE 3B - RESULTS OF CHEMICAL ANALYSES OF ANIONS AND CATIONS FROM SELECTED SAMPLING POINTS
(See Table 4 and Hughes et al. (1971a) for location) - Continued

Sample no.	Year tested	14 Bicarbonate[1] (ppm)	15 Bicarbonate[2] (ppm)	16 Bromine (ppm)	17 Carbonate (ppm)	18 Chloride[1] (ppm)	19 Chloride[2] (ppm)	20 Cyanide (ppm)	21 Fluoride[1] (ppm)	22 Fluoride[2] (ppm)	23 Nitrate (ppm)	24 Phosphate[1] (ppm)	25 Phosphate[2] (ppm)	26 Sulphate[1] (ppm)	27 Sulphate[2] (ppm)	28 Aluminum (ppm)	29 Arsenic[1] (ppm)
DupMM79	1970	450				25					<0.1*	ND	0.1*	67			
	1971	370		<0.006		<10	30*		0.5			<10		53	88*		0.003
	1973	500		0.39		17	57*		0.41					360	33*		.001
DupMM48	1969			0.3		64†		<0.005†	0.08†		0.93†	1.65†		85†		0.40†	<0.1†
DupMM59	1969			3.9		269†		<0.005†	0.15†		0.17†	6.50†		31†		0.70†	<0.1†
	1970	1350				230						ND		TR			
DupMM23	1971	590		0.90		160			0.2			<10		19			<0.004
	1973	660		1.5		290			0.27					49			.004
DupMM42	1973	1880		4.8		144	170*		0.17		0.1#	0.30*		2	14*		0.004
DupMM44	1969			5.4		287†		<0.005†	0.39†		0.65†	0.24†		<0.02†		0.30†	<0.1†
	1970	2780				86					<0.1*	ND	0.3*	ND			
	1971	4040		3.6		97	297*		<0.1			<10		7	<10*		0.016
DupMM61	1969			3.0		205†		<0.005†	0.44†		0.14†	0.50†		1.0†		0.20†	<0.1†
DupMM63	1969			12		946†		<0.005†	0.89†		0.50†	0.17†		1.0†		<0.50†	<0.1†
	1970	5050				370					1*	ND	PS*	ND			
	1971	5790		14		255	2100*		0.1			41		6	<10*		0.17
	1973	4850		12	230	275	1200*		0.23		<0.05#	0.40*		ND	60*		.0005
WinnLW10A	1970	480				53					<0.1*	ND	0.1*	ND			
	1971	510		0.87		75	325*		0.6			<10		49	PS*		0.029
	1973	570		3.4		280	265*		0.35	0.4*	<0.05#	0.5*		14	12*		.006
WinnLW12	1969			0.7		99†		<0.005†	0.34†		0.05†	0.87†		190†		<0.05†	0.1†
	1971	660		<0.5		23	81*		0.4			<10		91	145*		<0.001
	1973	640		0.85		58	100*		0.35	0.4*	0.3#	<0.01*		90	90*		.001
WinnLW13	1969			1.1		70†		<0.005†	0.23†		0.20†	1.30†		5†		0.50†	0.1†
	1970	1020				80					<0.1*	ND	0.1*	ND			
	1971	1140		0.76		260	270*		0.2			<10		6	<10*		0.008
	1973	690		0.43		48	90*		0.17	0.2*	<0.05#	0.40*		ND	2*		.0006

[1,2] Sample split for analysis at two laboratories.
[3] Methylene blue active substances (includes detergents).
ND - Not determined. TR - Trace.
PS - Poor sample or not suitable for testing.

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# - Analysis by Illinois Environmental Protection Agency.

TABLE 3B - RESULTS OF CHEMICAL ANALYSES OF ANIONS AND CATIONS FROM SELECTED SAMPLING POINTS
(See Table 4 and Hughes et al. (1971a) for location) - Continued

Sample no.	Year tested	14 Bicarbonate[1] (ppm)	15 Bicarbonate[2] (ppm)	16 Bromine (ppm)	17 Carbonate (ppm)	18 Chloride[1] (ppm)	19 Chloride[2] (ppm)	20 Cyanide (ppm)	21 Fluoride[1] (ppm)	22 Fluoride[2] (ppm)	23 Nitrate (ppm)	24 Phosphate[1] (ppm)	25 Phosphate[2] (ppm)	26 Sulphate[1] (ppm)	27 Sulphate[2] (ppm)	28 Aluminum (ppm)	29 Arsenic[1] (ppm)
WinnLW5B	1969			8.4		701†		<0.005†	0.54†		0.43†	2.75†		1.0†		<0.05†	<0.1†
	1970	2030				520					<0.1*	ND	0.1*	ND			
	1971	2200		6.5		293	775*		0.2			<10		2	<10*		0.01
	1973	2080		9.1		540	720*		0.17	0.2*	0.2#	0.8*		ND	75*		.005
WinnLW17	1969			5.8		429†		<0.005†	0.40†		0.50†	2.60†		13.6†		0.30†	<0.1†
	1970	3310			125	380					<0.1*	ND	0.5*	ND			
	1971	950		0.42			128*		0.2			<10		3	<10*		0.33
	1973	700		.03		221	245*		0.29	0.3*	<0.05#	0.50*		98	100*		.004
ElgLW6B	1969			2.3		102†		0.005†	0.37†		0.04†	3.25†		680†		0.40†	<0.1†
	1970	380				53					<0.1*	ND	0.1*	327			
	1971			<0.3		ND	135*		0.3			<10		2	<10*		0.003
	1973	1780		1.9		234			0.42					ND			.001
WoodLW1C	1969			0.3		91†		0.005†	0.15†		0.10†	5.90†		24†		0.20†	<0.1†
	1970	470				98					<0.1*	ND	0.1*	TR			
WoodLW6B	1973	710		1.3		68			0.40					818			.004
BlkLW1	1969			ND		1697†		<0.24†			0.70†	6.0†		680†		2.20†	4.3†
	1970	7320				1050					PS*	ND	PS*	91			
BlkLW2	1973	9500		25.0		3950	PS*		0.24	0.3*	PS#	0.28*		1250	2600*		0.11

[1,2] Sample split for analysis at two laboratories.
[3] Methylene blue active substances (includes detergents).
ND - Not determined. TR - Trace.
PS - Poor sample or not suitable for testing.

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# - Analysis by Illinois Environmental Protection Agency.

TABLE 3C - RESULTS OF CHEMICAL ANALYSES OF CATIONS FROM SELECTED SAMPLING POINTS
(See Table 4 and Hughes et al. (1971a) for location.)

Sample no.	Year tested	30 Arsenic[2] (ppm)	31 Barium (ppm)	32 Beryllium (ppm)	33 Boron[1] (ppm)	34 Boron[2] (ppm)	35 Cadmium[1] (ppm)	36 Cadmium[2] (ppm)	37 Calcium[1] (ppm)	38 Calcium[2] (ppm)	39 Chromium (ppm)	40 Copper[1] (ppm)	41 Copper[2] (ppm)	42 Iron (ppm)	43 Lead[1] (ppm)	44 Lead[2] (ppm)	45 Magnesium[1] (ppm)
DupLW6A	1969		0.30†	<0.1†	0.15	1.6†	<0.05†		91†		0.10†	<0.05†		0.40†	<.5	0.5†	38†
	1970				0.11				27			<0.01		0.7	<0.5		19
	1971				0.24				51	56*	<0.2	0.04		0.16	1.2		40
	1973	<0.002*			0.2*		<0.01	<0.01*	68	70.0*	<0.01#	<0.01	0.01*	7.0#	<0.1	<0.01*	36
DupLW14	1969		0.25†	<0.1†	0.27	<0.1†	<0.05†		72†		<0.05†	<0.05†		1.00†	<.5	0.5†	26†
	1970				0.26				35			0.25		0.2	<0.5		40
	1971				0.59				49	56*	<0.2	0.11		3.0	0.2		29
	1973	0.004*			0.4*		<0.01*	<0.01*	51	95.0*	0.02#	1.56	0.05*	11.8#	<0.1	0.02*	34
DupLW15	1969		0.15†	<0.1†	0.14	<0.1†	<0.05†		116†		0.10†	<0.05†		0.40†	<.5	1.1†	56†
	1970				0.17				50			<0.1		.44	<0.5		28
	1971				0.19				82	100*	<0.1	<0.01		1.1	0.2		47
	1973	<0.002*			0.2*		<0.01	<0.01*	125	105.0*	<0.01#	<0.01	0.03*	0.00#	<0.1	3.5*	67
DupLW16	1969		0.40†	<0.1†	0.31	<0.1†	<0.05†		224†		<0.05†	<0.05†		0.50†	<.5	0.5†	135†
	1970				1.06				99			<0.01		0.4	<0.5		48
	1971				0.32				137	156*	<0.1	<0.01		2.6	1.0		80
	1973	<0.002*			0.4*		<0.01	<0.01*	197	155.0*	<0.01#	<0.01	0.03*	2.8#	<0.1	<0.01*	99
DupLW6B	1969		0.30†	<0.1†	0.91	15.6†	<0.05†		102†		<0.05†	<0.05†		0.60†	<.5	1.0†	88†
	1970				0.78				59			.05		12.8	<0.5		43
	1971				0.50				59	68*	<0.2	<0.01		1.2	<0.1		80
	1973	0.020*			0.9*		<0.01	<0.01*	70	125.0*	<0.01#	1.07	0.04*	26.0#	<0.1	0.40*	69
DupLW12A	1969		0.30†	<0.1†	0.21	28.4†	<0.05†		66†		<0.05†	<0.05†		0.70†	<.5	1.0†	37†
	1970				0.16				37			<0.1		.01	<0.5		25
	1971				0.14				488	PS*	<0.2	<0.01		94.	2.4		242
	1973	0.004*			0.3*		<0.01	<0.01*	86	110.0*	0.02#	<0.01	0.02*	9.5#	<0.1	0.03*	50
DupLW11A	1969		0.20†	<0.1†	0.48	1.2†	<0.05†		98†		0.05†	<0.05†		0.90†	<.5	1.0†	28†
	1970				0.11				28			<0.01		0.4	<0.5		16
	1971				0.15				82		<5.4	0.12		25.6	1.9		31
	1973	<0.002*			0.2*		<0.01*	<0.01*	49	70.0*	<0.01#	<0.01	0.03*	4.0#	<0.1	0.02*	52
DupLW5B	1969		0.80†	<0.1†	5.35	96.8†	<0.05†		308†		0.15†	<0.05†		6.30†	<.5	0.5†	480†
	1970				4.2				71			<0.01		3.6	<0.5		160
	1971				4.04				103	100*	<0.2	.04		3.6	1.7		308
	1973	0.002*			4.2*		<0.01	<0.01*	41	110.0*	<0.01#	3.21	0.07*	16.0#	<0.1	0.05*	227

[1,2] Sample split for analysis at two laboratories.
[3] Methylene blue active substances (includes detergents).
ND - Not determined. TR - Trace.
PS - Poor sample or not suitable for testing.

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# - Analysis by Illinois Environmental Protection Agency.

TABLE 3C - RESULTS OF CHEMICAL ANALYSES OF CATIONS FROM SELECTED SAMPLING POINTS
(See Table 4 and Hughes et al. (1971a) for location.) - Continued

Sample no.	Year tested	30 Arsenic[2] (ppm)	31 Barium (ppm)	32 Beryllium (ppm)	33 Boron[1] (ppm)	34 Boron[2] (ppm)	35 Cadmium[1] (ppm)	36 Cadmium[2] (ppm)	37 Calcium[1] (ppm)	38 Calcium[2] (ppm)	39 Chromium (ppm)	40 Copper[1] (ppm)	41 Copper[2] (ppm)	42 Iron (ppm)	43 Lead[1] (ppm)	44 Lead[2] (ppm)	45 Magnesium[1] (ppm)
DupMM79	1970				0.05				57			<0.1		0.4	<0.5		37
	1971				0.09				88	112*	<0.2	.05		1.2	<0.1		37
	1973	0.016*			0.2*		<0.01	<0.01*	128	280*	0.04#	<0.01		26.0#	<0.1	0.04*	49
DupMM48	1969		0.20†	<0.1†		41.2†	<0.05†		131†		<0.05†	<0.05†		0.30†		0.5†	60†
DupMM59	1969		1.2†	<0.1†	0.13	25.4†	<0.05†		111†		0.10†	<0.05†		1.20†	<.5	1.0†	150†
	1970				1.31				72			<0.1		1.0	<0.5		62
DupMM23	1971				0.34				106		<0.2	.06		2.0	0.3		73
	1973						<0.01		183			1.36			0.1		77
DupMM42	1973	0.003*			3.2*		<0.01	<0.01*	227	170.0*	<0.01#	<0.01	0.02*	22.5#	<0.1	0.02*	35
DupMM44	1969		7.5†	<0.1†	2.70	20.4†	<0.05†		1500†		<0.05†	<0.05†		60.0†	<.5	0.5†	177†
	1970				2.09				267			<0.1		8.8	<0.5		45
	1971				2.82				800	784*	<0.2	.06		93.	<0.1		145
DupMM61	1969		0.30†	<0.1†		20.0†	<0.05†		156†		0.05†	<0.05†		100.†		1.0†	98†
DupMM63	1969		3.50†	<0.1†		35.2†	<0.05†		447†		<0.05†	<0.05†		12.0†		1.0†	440†
	1970				3.57				39			<0.1		2.	<0.5		193
	1971				4.63				94	108*	<0.2	0.06		2.8	1.7		330
	1973	0.090*			7.1*		<0.01	<0.01*	107	40.0*	0.04#	3.21		10.8#	<0.1	0.01*	195
WinnLW10A	1970				0.75				27			<0.1		.13	<0.5		11
	1971				0.70				33	PS	<0.2	0.4		23.	1.9		16
	1973	0.010*			1.2*		<0.01	<0.01*	133	362.5*	0.04#	<0.01	0.09*	36.0#	<0.1	0.16*	59
WinnLW12	1969		0.15†	<0.1†	0.60	26.4†	<0.05†		72†		0.05†	<0.05		0.20†	<.5†	0.5†	50†
	1971				0.52				96	104*	<0.2	<0.01		4.8	1.9		44
	1973	<0.002*			0.8*		<0.01	<0.01*	103	90.0*	<0.01#	<0.01	<0.01*	0.6#	<0.1	<0.01*	45
WinnLW13	1969		0.15†	<0.1†		24.8†	<0.05†		109†		0.05†	<0.05†		11.0†		1.0†	67.5†
	1970				0.67				74			<0.1		14.6	<0.5		29
	1971				0.98				126	128*	<0.2	.02		45.	2.4		71
	1973	<0.002*			0.7*		<0.01	<0.01*	150	135.0*	<0.01	<0.01	<0.01*	85.0#	<0.1	0.02*	30

[1,2] Sample split for analysis at two laboratories.
[3] Methylene blue active substances (includes detergents).
ND - Not determined. TR - Trace.
PS - Poor sample or not suitable for testing.

— - Analysis by Illinois State Geological Survey.
* - Analysis by Illinois State Department of Public Health.
† - Analysis by Tenco Hydro/Aerosciences, Inc.
# - Analysis by Illinois Environmental Protection Agency.

TABLE 3C - RESULTS OF CHEMICAL ANALYSES OF CATIONS FROM SELECTED SAMPLING POINTS
(See Table 4 and Hughes et al. (1971a) for location.) - Continued

Sample no.	Year tested	30 Arsenic[2] (ppm)	31 Barium (ppm)	32 Beryllium (ppm)	33 Boron[1] (ppm)	34 Boron[2] (ppm)	35 Cadmium[1] (ppm)	36 Cadmium[2] (ppm)	37 Calcium[1] (ppm)	38 Calcium[2] (ppm)	39 Chromium (ppm)	40 Copper[1] (ppm)	41 Copper[2] (ppm)	42 Iron (ppm)	43 Lead[1] (ppm)	44 Lead[2] (ppm)	45 Magnesium[1] (ppm)
WinnLW5B	1969		0.50†	<0.1†		37.2†	<0.05†		109†		0.05†	<0.05†		13.65†		0.5†	171†
	1970				1.5				31			<0.1		3.7	<0.5		66
	1971				1.9				84	68*	0.2	.04		20.4	1.9		145
	1973	<0.002*			2.4*		<0.01	<0.01*	16	72.5*	0.03#	0.97	0.02*	20.2#	<0.1	0.07*	145
WinnLW17	1969		0.15†	<0.1†		-†	0.05†		100†		0.05†	<0.05†		96.0†		1.0†	165†
	1970				1.7				75			0.06		0.7	<0.5		84
	1971				0.38				96	160*	<0.2	.01		0.4	2.4		167
	1973	0.100*			0.5*		<0.01	<0.01*	226	210.0*	0.01#	<0.01	0.09*	46.5#	<0.1	0.04*	51
ElgLW6B	1969		0.20†	<0.1†		-†	<0.05†		209†		<0.05†	<0.05†		0.40†		0.1†	159†
	1970				0.52				52			<0.1		4.8	<0.5		48
	1971				2.02				244	100*	<0.2	0.6		32.	1.7		97
	1973						<0.01		79			1.07			<0.1		307
WoodLW1C	1969		0.20†	0.1†		-†	<0.05†		115†		0.05†	<0.05†		0.60†		1.0†	59†
	1970				0.2				55			<0.1		2.8	0.5		21
WoodLW6B	1973						<0.01		138			1.66			<0.1		193
BlkLW1	1969		8.50†	<0.1†		320†	<0.05†		2150		0.20†	<0.05†		5500†		1.3†	600
	1970				6.6				439			.08		39	.50		615
BlkLW2	1973	0.060*			PS*		6.86	0.19*	3560	3050.0*	0.15#	1.95	0.19*	1750.0#	<0.1	1.22*	1090

[1,2] Sample split for analysis at two laboratories.
[3] Methylene blue active substances (includes detergents).
ND - Not determined. TR - Trace.
PS - Poor sample or not suitable for testing.

— - Analysis by Illinois State Geological Survey.
* - Analysis by Illinois State Department of Public Health.
† - Analysis by Tenco Hydro/Aerosciences, Inc.
# - Analysis by Illinois Environmental Protection Agency.

TABLE 3D - RESULTS OF CHEMICAL ANALYSES OF CATIONS FROM SELECTED SAMPLING POINTS
(See Table 4 and Hughes et al. (1971a) for location.)

Sample no.	Year tested	46 Magnesium[2] (ppm)	47 Manganese[1] (ppm)	48 Manganese[2] (ppm)	49 Mercury[1] (ppm)	50 Mercury[2] (ppm)	51 Nickel[1] (ppm)	52 Nickel[2] (ppm)	53 Potassium[1] (ppm)	54 Potassium[2] (ppm)	55 Selenium (ppm)	56 Silver (ppm)	57 Sodium[1] (ppm)	58 Sodium[2] (ppm)	59 Zinc[1] (ppm)	60 Zinc[2] (ppm)
DupLW6A	1969		<0.05†						2†		<0.1†	<0.1†	12†		.83	0.15†
	1970														0.1	
	1971	34*	<0.2		0.006				5.0	2.6#	<0.2		23	18.#	0.7	0.55#
	1973	45.0#	2.1	0.09#	0.005	0.002#	<.05	<0.1#	3	1.8#	<0.01	<.01#	5	16.0*	0.23	3.2#
DupLW14	1969		0.17†						2.7†		<0.1†	<0.1†	50†		.54	2.90†
	1970								3.5				52.7		0.2	
	1971	33#	0.49		0.005				6.0	11.5#	<0.2		61	44#	0.3	0.8#
	1973	50.0#	0.02	0.36#	0.003	0.002#	<.05	<0.1#	6	3.4#	<0.01#	<0.01#	42	42.0*	.53	0.4#
DupLW15	1969		<0.05*						2.6†		<0.01†	<0.1†	52†		<0.1	0.25†
	1970								3.5				112.6		2	
	1971	56#	<0.2		0.003				5.0	3.1#	<0.2		48	63.#	0.26	<0.05#
	1973	65.0#	0.15	0.05#	.0002	0.002#	<.05	<0.1#	6	3.8#	<0.01#	<0.01#	148	160.0*	0.22	0.2#
DupLW16	1969		0.10†						2.7†		0.1†	0.1†	112†		0.11	0.20†
	1970								8.3				230.6		.35	
	1971	100#	0.42		0.004				11	7.5#	0.2		105	150#	.08	<0.05#
	1973	97.5#	0.02	0.06#	.0015	0.002#	<.05	<0.1#	6	4.1#	<0.01#	<0.01#	123	240.0*	<.01	0.1#
DupLW6B	1969		0.06†						100†		<0.1†	<0.1†	74†		<.1	4.50†
	1970								67.6				108.7		4	
	1971	86#	<0.5		0.003				85	55.#	<0.2		102	90.#	0.25	0.2#
	1973	100.0#	0.02	0.61#	.0012	0.2#	0.08	<0.1#	16	85.0#	<0.01#	<0.01#	19	75.0*	0.24	4.4#
DupLW12A	1969		0.07†						2.7†		<0.1†	<0.1†	61†		<.1	0.15†
	1970								4				103		ND	
	1971	41#	4.7		0.004				28	115#	<0.3		640	434.#	174	9.0#
	1973	65.0#	0.02	0.33#	.0011	0.002#	<.05	<0.1#	5	3.8#	<0.01#	<0.01#	139	175.0*	.01	3.6#
DupLW11A	1969		0.06†						2.5†		0.1†	0.1†	49†		9.1	0.30†
	1970								3.3				69.9		ND	
	1971		1.4		<0.006				3		<0.7		>910		11.0	
	1973	42.5#	0.02	0.08#	.0008	0.2#	<.05	<0.1#	4	2.7#	<0.01#	<0.01#	134	117.5*	.01	1.1#
DupLW5B	1969		0.06†						610†		0.1†	0.1†	810†		.13	0.40†
	1970														4.5	
	1971	340#	<0.8		0.003				588	550.#	<0.2		944	820#	<.01	0.05#
	1973	212.5#	0.11	0.11#	.007	0.3#	0.12	<0.1#	308	310.0#	<0.01#	<0.01#	476	475.0*	<.01	0.2#

[1,2] Sample split for analysis at two laboratories.
[3] Methylene blue active substances (includes detergents).
ND - Not determined. TR - Trace.
PS - Poor sample or not suitable for testing.

— - Analysis by Illinois State Geological Survey.
* - Analysis by Illinois State Department of Public Health.
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# - Analysis by Illinois Environmental Protection Agency.

TABLE 3D - RESULTS OF CHEMICAL ANALYSES OF CATIONS FROM SELECTED SAMPLING POINTS
(See Table 4 and Hughes et al. (1971a) for location.) - Continued

Sample no.	Year tested	46 Magnesium[2] (ppm)	47 Manganese[1] (ppm)	48 Manganese[2] (ppm)	49 Mercury[1] (ppm)	50 Mercury[2] (ppm)	51 Nickel[1] (ppm)	52 Nickel[2] (ppm)	53 Potassium[1] (ppm)	54 Potassium[2] (ppm)	55 Selenium (ppm)	56 Silver (ppm)	57 Sodium[1] (ppm)	58 Sodium[2] (ppm)	59 Zinc[1] (ppm)	60 Zinc[2] (ppm)
DupMM79	1970								1.0				8.0		0.13	
	1971	46#	0.30		0.004				1.3	0.3#	<0.2		6.5	4.9#	<.01	<0.05#
	1973	130.0#	0.02	1.06#	0.005	0.4#	<.05	<0.1#	1.3	3.1#	0.01#	<0.01#	6	15.5*	<.01	1.0#
DupMM48	1969		0.15†						0.75†		<0.1†	<0.1†	22†			1.70†
DupMM59	1969		0.09†						56.5†		<0.1†	<0.1†	188†		<0.10	1.40†
	1970								54.1				171.8		ND	
DupMM23	1971		<0.4		0.006				8.9		<0.2		128		<.01	
	1973		0.18		.0004		<.05		6				144		3.66	
DupMM42	1973	40.0#	0.05	0.12#	.0003		<.05	<0.1#	133	121.0#	<0.01#	<0.01#	166	185.0*	<.01	0.6#
DupMM44	1969		0.83†						164†		<0.1†	<0.1†	236†		.34	0.15†
	1970								119.5				229.7		.50	
	1971	156#	1.1		<0.001				145	115#	<0.2		236	213#	<.01	0.05#
DupMM61	1969		0.24†						85†		0.1†	0.1†	63†			0.10†
DupMM63	1969		0.09†						220†		0.1†	0.1†	615†			0.05†
	1970								419.7				1083.6		0.3	
	1971	360#	<3		0.004				587	145.#	<0.2		1274	1200.#	<.01	0.05#
	1973	200.0#	0.07	0.03#	0.005		0.30	0.3#	571	620.0#	<0.01#	<0.01#	934	1000.0*	<.01	<0.05#
WinnLW10A	1970								6.0				157.7		ND	
	1971	3.5#	0.8		0.006				10	6.6#	0.3		329	244.#	29.5	0.35#
	1973	150.0#	.04	1.60#	.0008	0.3#	<.05	<0.1#	8	11.5#	<0.01#	<0.01#	142	127.5*	<.01	0.4#
WinnLW12	1969		0.006†						4†		<0.1†	<0.1†	110†		0.10	1.25†
	1971	50#	0.41		0.005				3.7	3.2#	0.2		166	165.#	0.3	<0.05#
	1973	40.0#	0.02	0.00#	0.006	0.2#	<.05	<0.1#	5	3.4#	<0.01#	<0.01#	148	167.5*	2.36	1.0#
WinnLW13	1969		0.20†						39†		<0.1†	<0.1†	34†			0.10†
	1970								38.2				71.5		0.5	
	1971	7.0#	0.39		0.003				73	66.	<0.3		165	120.#	0.3	<0.05#
	1973	40.0#	0.69	0.74#	0.001	PS#	<.05	<0.1#	7	11.5#	<0.01#	<0.01#	48	53.0*	<.01	0.3#

[1,2] Sample split for analysis at two laboratories.
[3] Methylene blue active substances (includes detergents).
ND - Not determined. TR - Trace.
PS - Poor sample or not suitable for testing.

— - Analysis by Illinois State Geological Survey.
* - Analysis by Illinois State Department of Public Health.
† - Analysis by Tenco Hydro/Aerosciences, Inc.
# - Analysis by Illinois Environmental Protection Agency.

TABLE 3D - RESULTS OF CHEMICAL ANALYSES OF CATIONS FROM SELECTED SAMPLING POINTS
(See Table 4 and Hughes et al. (1971a) for location.) - Continued

Sample no.	Year tested	46 Magnesium[2] (ppm)	47 Manganese[1] (ppm)	48 Manganese[2] (ppm)	49 Mercury[1] (ppm)	50 Mercury[2] (ppm)	51 Nickel[1] (ppm)	52 Nickel[2] (ppm)	53 Potassium[1] (ppm)	54 Potassium[2] (ppm)	55 Selenium (ppm)	56 Silver (ppm)	57 Sodium[1] (ppm)	58 Sodium[2] (ppm)	59 Zinc[1] (ppm)	60 Zinc[2] (ppm)
WinnLW5B	1969		0.09†						220†		<0.1	<0.1†	348†			0.60†
	1970								180.3				330.9		0.2	
	1971	150#	<0.8		0.004				80	155.#	<0.2		428	353#	1.7	0.3#
	1973	137.5#	0.07	0.17#	.0013	0.5#	<.05	<0.1#	42	175.#	<0.01#	<0.01#	100	360.0#	0.21	2.0#
WinnLW17	1969		1.14†						168†		<0.1†	<0.1†	298†			1.50†
	1970								108.2				348.1		0.05	
	1971	105#	1.3		<0.002				17	33.#	<0.2		127	113.#	2.2	0.05#
	1973	55.0#	0.02	2.60#	.0011	0.2#	<.05	<0.1#	7	5.5#	<0.01#	<0.01#	140	135.0#	<0.1	1.0#
ElgLW6B	1969		0.11†						38†		<0.1†	<0.1†	98†			0.35†
	1970								18.8				74.2		7	
	1971	188#	0.41		0.005				32	15.5#	<0.2		127	120.#	0.8	4.#
	1973		0.02		.0011		<.05		40				130		0.32	
WoodLW1C	1969		0.11†						7†		<0.1†	<0.1†	46†			3.85†
	1970								9.0				72.5		7.5	
WoodLW6B	1973		0.13		.0011		0.15		21				141		3.42	
BlkLW1	1969		1.66†						790†		2.7†	<0.1†	900†			40.0†
	1970								786.3				1299.6		.40	
BlkLW2	1973	900.0#		6.40#		0.9#	0.79	1.4#	1260	1150.0#	<0.01#	0.07#	2990	3150.0#	159	146.0#

[1,2] Sample split for analysis at two laboratories.
[3] Methylene blue active substances (includes detergents).
ND - Not determined. TR - Trace.
PS - Poor sample or not suitable for testing.

— - Analysis by Illinois State Geological Survey.
* - Analysis by Illinois State Department of Public Health.
† - Analysis by Tenco Hydro/Aerosciences, Inc.
# - Analysis by Illinois Environmental Protection Agency.

TABLE 4 - WELLS SAMPLED, SAMPLING POINTS OR ZONES, AND AGE OF REFUSE

Well	Sampled zone	Age of nearest refuse
Du Page		
DupLW6a	Interbedded sand, well not polluted, samples 17.33' below top of till	1952
DupLW14	Samples 15.19' below top of till	1952
DupLW15	Samples 4.31' below top of till	1952
DupLW16	Samples 2.57' below top of till	1952
DupLW6B	Screen 5' below base of refuse	1952
DupLW12A	Samples 7.47' below top of till	1963
DupLW11A	Samples 2.30' below top of till	1963
DupLW5B	Screen 3' below refuse in sand	1963
DupMM79	Samples middle of surficial sand 900' south of fill	1957
DupMM48	Samples surficial sand 650' south of fill	1957
DupMM59	Samples base of surficial sand 325' south of fill	1957
DupMM23	Samples middle of surficial sand 250' south of fill	1957
DupMM42	Samples surficial sand 39' south of fill	1957
DupMM44	Samples surficial sand 30' south of fill	1957
DupMM61	Samples refuse	1955
DupMM63	Samples near base of refuse	1960
Winnetka		
WinnLW17	Samples near base of refuse (7/11/67)	1967
WinnLW10A	Samples till 23' below refuse	1967
WinnLW12	Samples transition zone, 7' below refuse	1953
WinnLW13	Samples refuse	1953
WinnLW5B	Samples refuse	1948
Elgin		
ElgLW6B	Samples near base of refuse	1964
Woodstock		
WoodLW6B	Samples near base of refuse	1961?
Blackwell Forest Preserve		
BlkLW1	Samples refuse probably "squeezed" leachate, in part	-
BlkLW2	Samples refuse probably "squeezed" leachate, in part	-

*See Hughes et al. (1971a) for maps of the landfills.

DISCUSSION

The data presented apply only to landfills investigated in this study, and cannot be directly extrapolated to other landfills in other areas. However, there are a number of general conclusions that can be made:

1) Infiltration into, and presumably discharge from, a landfill is primarily dependent on precipitation but it is also strongly affected by such factors as winter thaw, runoff (particularly from frozen ground), evapo-transpiration, and the time between precipitation events. Somewhat less than one-half of the precipitation on the landfill infiltrated to produce leachate. Covers on the landfills were not constructed to reduce infiltration; they were relatively flat and not suitably sloped for good drainage.

2) It required 4 to 7 years to bring the refuse in these disposal sites to field capacity and 10 to 15 years to complete the growth of the ground-water mounds.

3) Dissolved solids that are produced from the leaching of refuse are removed from the ground water in varying amounts as they move into the subsurface. The data presented here reflected attenuation under saturated flow conditions below the water table.

4) Strictly speaking, all of the landfills studied in this investigation contaminated the ground water. However, in no case was the degree of contamination great enough to have an appreciable or noticeable effect on a nearby ground- or surface-water resource. In each case, for the past 20 to 30 years, the surrounding environment has been able to accept the contaminants from the landfill without a significant adverse effect.

REFERENCES

Hughes, G. M., R. A. Landon, and R. N. Farvolden, 1971a, Hydrogeology of solid waste disposal sites in northeastern Illinois: Demonstration Grant G06-EC-00006 from the Federal Solid Waste Management Program, U.S. Environmental Protection Agency, 154 p.

Hughes, G. M., R. A. Landon, and R. N. Farvolden, 1971b, Summary of findings on solid waste disposal sites in northeastern Illinois: Illinois State Geological Survey Environmental Geology Notes No. 45, 25 p.

APPENDIX

ANALYTICAL PROCEDURES

Substance	1969			1970		1971		1973	
	Tenco	ISGS	ISDPH	ISGS	ISDPH	ISGS	IEPA	ISGS	IEPA
Alkalinity	1	3	-	-	-	-	3	-	3
Biological oxygen demand	2	-	-	-	13	-	-	-	-
Chemical oxygen demand	2	-	-	-	2	-	21	-	21
Conductivity	-	-	-	14	-	14	15	14	15
Total hardness	3	-	-	-	-	-	-	-	3
Hexane solubles	4	-	-	-	-	-	-	-	-
M.B.A.S.	5	-	-	-	17	-	-	-	-
Pesticides	6	-	-	-	-	-	-	-	-
pH	-	14	-	14	-	14	-	14	-
Total dissolved solids	23	-	-	23	-	23	-	23	-
Ammonia	-	-	-	-	-	-	-	-	17
Bicarbonate	-	-	-	22	-	22	-	22	-
Bromine	-	16	-	-	-	16	-	16	-
Carbonate	-	-	-	22	-	-	-	-	-
Chlorine	7	-	-	3	-	3	17	3	17
Cyanide	8	-	-	-	-	-	-	-	-
Fluoride	9	-	-	-	-	18	-	18	18
Nitrate nitrogen	10	-	-	-	10	-	-	-	17
Phosphate	2	-	-	19	5	19	-	-	17
Sulfate	11	-	-	19	-	19	11	19	17
Aluminum	12	-	-	-	-	-	-	-	-
Arsenic	12	-	-	-	-	16	-	16	12
Barium	12	-	-	-	-	-	-	-	-
Boron	5	5	-	5	-	5	-	-	17
Cadmium	12	-	-	-	-	-	-	12	12
Calcium	12	-	-	3	-	3	12	3	12
Chromium	12	-	-	-	-	12	-	-	12
Copper	12	-	-	12	-	12	-	12	12
Iron	12	-	-	3	-	3	-	-	12
Lead	12	12	-	12	-	12	-	12	12
Magnesium	12	-	-	3	-	3	12	3	12
Manganese	12	-	-	-	-	16	-	16	12
Mercury	-	-	-	-	-	16	-	16	5
Nickel	-	-	-	-	-	-	-	12	12
Potassium	12	-	-	20	-	20	12	20	12
Selenium	12	-	-	-	-	16	-	16	12
Silver	12	-	-	-	-	-	-	-	12
Zinc	12	12	-	12	-	12	12	12	12

Note: Analytical procedures that were used in the laboratories have been numbered and are listed on page 24 of the appendix. Analyses were made at the following laboratories:

Tenco - Tenco Hydro/Aerosciences, Inc.
ISGS - Illinois State Geological Survey
ISDPH - Illinois State Department of Public Health
IEPA - Illinois Environmental Protection Agency

PROCEDURES

1 - Potentiometric method. SM, p. 368*
2 - SM - 20 day*
3 - Titrated. SM*
4 - FWPA method - antimony tartrate, ascorbic acid
5 - Spectrophotometric
6 - Federal Water Pollution Control Agency (Federal Water Quality Agency)
7 - Argentometric
8 - Pyridine - pyralzolone. SM, p. 455*
9 - SPADNS - SM, p. 144*
10 - Phenyldisulfonic acid
11 - Turbidimetric
12 - Atomic absorption spectrophotometry
13 - SM - 5 day*
14 - Conductivity - meter in field. pH - meter and paper in field.
15 - Meter in laboratory
16 - Instrumental nuclear activation analysis
17 - Technicon
18 - Ion specific electrode
19 - Precipitation as phosphomolybdate
20 - Flame photometry
21 - Reflux method. SM*
22 - Double titration
23 - Volumetric evaporation.

*Procedures used are outlined in American Public Health Association, American Water Works Association, and Water Pollution Control Federation, 1965, Standard methods for the examination of water and wastewater including bottom sediments and sludges: 12th ed., New York, American Public Health Associations, 769 p.

Readers may contact the Illinois State Geological Survey, Natural Resources Building, Urbana, IL 61801 for a more detailed description of specific methods.

ENVIRONMENTAL GEOLOGY NOTES SERIES

(Exclusive of Lake Michigan Bottom Studies)

1. Controlled Drilling Program in Northeastern Illinois. 1965.
2. Data from Controlled Drilling Program in Du Page County, Illinois. 1965.
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